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Ranking Secondary Channels for Restoration Using an Index Approach

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SUMMARY: There are over 100 secondary channels in the Lower Mississippi River depending on river stage. Most have closure dikes in the upper reaches or throughout the channel to redirect flow towards the main channel to increase navigable depths. Recent environmental engineering practices in Corps Districts have recognized that many secondary channels can be reconnected without compromising navigation benefits. To accomplish this process, three indices were developed to rank the relative importance of secondary channels: Habitat Quality, Economy of Restoration, and Priority. Using aerial, geo-referenced video and aerial photography, five attributes or metrics of secondary channels were measured to establish an Index of Habitat Quality:

- Presence of gravel.
- Number of macrohabitats.
- Percent forested riparian on the island-side.
- Percent forested riparian on the land-side.
- Distance to Mississippi River mainline levee or natural bluff.

The Economy of Restoration Index is a linear relationship between the number of dikes in a secondary channel requiring notching to restore flow and cost of construction. The Priority Index is the product of the Habitat Quality and Economy of Restoration Indices. Results indicate the presence of numerous side channels having moderate habitat quality with a relatively high number of dikes and only a small number of high-ranking channels that should be considered for conservation. Secondary channels can be restored relatively inexpensively, influencing large aquatic areas of riverine habitat, and most channels are within the Corps' authorized boundaries, making it likely that cooperative restoration efforts with resource agencies will result in positive habitat gains.

INTRODUCTION: The Lower Mississippi River (LMR) extends almost 1,000 miles from the mouth of the Ohio River to the Gulf of Mexico. Along its course, there are approximately 110 secondary channels between river miles 132 and 946 (Williams and Clouse 2003). Secondary channels are referred to by various names – chutes, abandoned channels, and sloughs.

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Geomorphically, they form islands as the secondary channel cuts through the floodplain before rejoining the main channel. The secondary channel captures less flow than the main channel, and can become dewatered at low river stages.

Biologically, secondary channels function similarly to both main channel and floodplain habitats. There are areas of strong current with substrates of sand and gravel, and other areas of slackwater with connections to backwaters and lakes. Flowing water supports rheophilic fishes such as suckers, minnows, and darters that are relatively intolerant to habitat changes. Backwaters provide nursery areas for both freshwater and estuarine fishes. Overall habitat heterogeneity in secondary channels supports a diverse assemblage of invertebrates and fishes and contributes to the overall health of the aquatic system (Baker et al. 1991, Simons et al. 2001). Consequently, secondary channels provide well-defined gradients between flowing and non-flowing water, are highly productive, and export detritus, plankton, and fish to the main channel and the Gulf of Mexico.

As part of the Mississippi River and Tributaries (MR&T) project authorized by Congress in 1928 to control floods and facilitate year-round navigation, the Corps of Engineers began to construct closure dikes in secondary channels to shunt more water into the main channel during low flows (Figure 1). This action reduced the need for costly dredging to remove sediment accretion in the main channel that hinders commercial navigation. Most closure dikes were constructed prior to passage of environmental legislation in the early 1970's. Today, Corps of Engineer Districts recognize the biological and ecological importance of secondary channels and are beginning to notch closure dikes and restore flow without compromising navigable depths in the main channel (Figure 2).

The Lower Mississippi River Conservation Committee (LMRCC) is a coalition of state and federal agencies promoting conservation and sustainable use of the LMR's natural resources. The LMRCC initiated a series of state-level planning meetings from 2001 – 2004 to identify habitat restoration opportunities along the Lower Mississippi River. Referred to as the Mississippi River Conservation Initiative, state biologists and other planning personnel identified a total of 239 LMR sites in Arkansas, Kentucky, Tennessee, Mississippi, and Louisiana considered important habitats requiring some form of restoration. From 2006-2008, a series of LMRCC meetings were held and a decision-support model was developed using multicriteria decision analysis to rank the habitat significance of 220 restoration projects (excluding boat ramps and a few other minor categories) identified by representatives of the states bordering the Mississippi River during meetings held in the early 2000's (Boysen et al., in preparation). The Decision Support Model (DSM) ranked alternatives based on input from participants on how habitat characteristics of each alternative should be weighted (Boysen et al., in preparation). Based on group consensus, improving hydraulic connections between main and secondary channels was selected as the top restoration priority.

For planning purposes, an objective assessment method was required to quantify habitat value for each secondary channel in the LMR. Such a method can be used for establishing restoration priorities according to ranked habitat value (e.g., selecting highly ranked channels) and return on investment (e.g., Habitat Units gained, sensu U.S. Fish and Wildlife Service (USFWS) 1980). The purpose of this article is to present an index-based method to quantify habitat value of

a. Closing dike at upstream reach of secondary channel.

b. Closing dikes in a secondary channel of the Lower Mississippi River.

Figure 1. Closing dikes.

Figure 2. Notches through secondary channel dikes.

secondary channels in the Lower Mississippi River using remotely sensed data and relative cost of restoration based on the number of dikes requiring notching to restore flow. An approach utilizing both habitat value and cost estimates to prioritize secondary channels for restoration will aid in the planning process for future restoration projects.

METHODS: Remotely sensed data were used to evaluate LMR secondary channels. The Corps of Engineers, Mississippi Valley Division obtains aerial, geo-referenced video of the LMR, including most secondary channels, to evaluate the condition of or need for channel training structures (e.g., dikes, revetment). Video was taken during low water in October and November 2007 when the river was less than +10 Low Water Reference Plane (LWRP) at the Vicksburg, MS gage. The LWRP is defined as the water elevation at which flows are greater for 97% of the time over the period of record. After viewing the video using Red Hen software, it was determined that the quality was more than sufficient to measure and identify habitat attributes.

Three indices were developed from the video, aerial photography, and navigation chart data. First, an Index of Habitat Quality (I_h) incorporated metrics that considered geomorphic, structural, and hydraulic features of secondary channels. It was assumed that greater habitat diversity results in greater habitat value to aquatic fauna inhabiting these channels. Five metrics were selected that regulated biological assemblages that could be quantified from the video and photography (Table 1). Each metric could be quantified from the video (percent gravel, number of habitats) or aerial photography (distance to levee, percent forested riparian). Metrics represented structural and hydrogeomorphic attributes that influence habitat quality, and were not redundant. Metrics used in the I_h were also hierarchal in scale: substrate => channel => floodplain.

Guidance and rules were established when viewing the video and taking measurements from the photography to provide consistency in metric quantification (Appendix A). Two of the metrics were counts and measurements (number of habitats and distance to levee, respectively), two were estimates of percent forested coverage on land and island side measured in 25% increments ranging from 0 to 100, and one was an estimate of relative abundance (gravel, see Appendix A). A score sheet was developed for each metric and data were obtained from the appropriate information source (i.e., video, photography, or both). At least two people collaboratively agreed upon scores, resolving differences of opinion during viewing.

Table 1. Rationale for metrics used in the secondary channel habitat index (I_h).

Metric	Metric Implications
Abundance of gravel	Gravel represents stable habitat used by riverine fishes, including endangered sturgeon, for spawning and feeding
Number of habitats	Greater habitat diversity corresponds to greater faunal diversity
Percent of forested riparian - landside	Trees provide shade and woody debris, filter sediment-laden water, and stabilize banks. Functions as a floodplain
Percent of forested riparian – Island	Trees provide shade and woody debris, filter sediment-laden water, and stabilize banks. Functions as a channel littoral zone
Distance to levee	Greater distance to levee results in a more expansive floodplain used by a variety of fishes that move laterally for spawning, rearing, and feeding

Metric values were scored 0.33 (low value), 0.66 (medium value), or 1.0 (high value) based on distribution quantiles (25, 50, 75%, respectively) of the variable. In addition, a minimum value of 0.1 was assigned to the 5% quantile or less to facilitate multiplicative functions using near zero values. Therefore, the actual scoring range for each metric was 0.1, 0.33, 0.66, and 1.0 (Table 2).

Table 2. Rationale for assigning metric values.

Metric Value	Assumption
0.1	Minimum value (habitat attribute marginal or absent)
0.33	25% quantile (degraded, impacted, or least “natural”)
0.66	50% quantile or median (impacted, moderately natural)
1.00	75% quantile (relatively unimpacted, natural)

The index of habitat quality (I_h) was the average value of the five metrics computed as follows:

$$I_h = \frac{\sum (m_i / w_i)}{n} \tag{1}$$

where

I_h = index of habitat quality
m_i = value of metric i
w_i = maximum possible score of metric i
n = number of metrics

The Economy of Restoration Index (I_e) was an assumed linear relationship between index score and number of dikes (Table 3). The index ranged from 0.1 (highest cost; highest number of dikes to notch) to 1.0 (no dikes present in the secondary channel, no cost). The highest number of dikes in a secondary channel was nine or greater. Intervening values indicated different site access requirements and amount of sediment requiring removal. The number of dikes was determined from the 2007 navigation maps (*http://www.mvd.usace.army.mil/navbook/riverMain.aspx*).

Table 3. Cost Index scores based on number of dikes present in a secondary channel.

Number of Dikes	Cost Index Score	Rationale
0	1.0	No construction costs
1 2	0.9 0.8	Minimal construction costs; access usually required on only one reach (upper or lower)
3 4	0.7 0.6	Access to entire channel necessary; value incorporates mean and median number of dikes
5 6 7 8	0.5 0.4 0.3 0.2	Access to entire channel necessary; high degree of sedimentation
>8	0.1	Maximum number of dikes and construction costs

A Priority Index (I_p), which ranks the secondary channel according to its habitat value and cost of restoration, was then calculated:

$$I_p = I_h I_e \tag{2}$$

I_p can range from a theoretical low of 0.01 (marginal or intermittent habitat suitability, maximum cost) to 1.0 (maximum habitat suitability, no cost).

The area of each secondary channel was measured from aerial photography. Using TerraServer, a scene of the secondary channel was selected at river stages closely matching the date of the Red Hen video. Secondary channel width was measured from three locations (upper, middle, and lower reach) and a mean width was calculated (Appendix A). The linear distance of the secondary channel was also measured from the TerraServer photography and total acres were determined (Appendix A).

RESULTS: Indices were developed from data collected in 53 side channels ranging in location from river mile 337 (near Old River Control Structure, LA) to 935 (near the mouth of the Ohio River). With a few exceptions, all secondary channels were selected by state agencies for restoration as part of the LMRCC Lower Mississippi River Conservation Initiative (*http://www.lmrcc.org/MRCI.htm*). The state-level planning meetings from 2001 – 2004 identified 77 secondary channels for restoration, but some were redundant with other states or they were reclassified into some other habitat category (i.e., backwater or main channel dikes) once detailed examination of the site occurred using aerial photography and video. Therefore, the total number used in this analysis represents all of the side channels identified by state biologists with the exceptions noted above. The 53 side channels ranged in length from 0.8 to 8.4 miles, the average size was 319 acres, and the maximum size was almost 1134 acres (Table 4).

Metric values were scored to indicate minimum to good attributes of secondary channels (Table 5). Gravel was not detected in 32% of the secondary channels evaluated (17 of 53). Less than 10% of the secondary channels had high abundance of gravel. Gravel was usually concentrated at the upstream reach of the island where high water velocities persist at river crossings. Maximum number of habitats identified in secondary channels collectively was eight (see Appendix A for list of habitats), but the maximum identified in any one secondary channel was six (Table 5). Overall, secondary channels had an average of three habitats. The most common habitat types were runs and pools and the least was tributary mouths. Average percent forested area was less on islands compared to landside, but both ranged from 0 to 100%. Secondary channels averaged about 2 miles from the levee with a maximum distance of 8 miles.

Table 4. Size of secondary channels used in index development, Lower Mississippi River, n=53.

Variable	Mean	Std Dev	Minimum	Maximum
River Mile	634.9	151.3	337.0	935.0
Length, miles	3.1	1.6	0.8	8.4
Ave. width, feet	931	413	326	2122
Acres	319	247	29	1134

Table 5. Metric values used in index development, Lower Mississippi River, n=53.

Variable	Mean	Std Dev	Minimum	Maximum
Gravel[1]	1.0	0.9	0.0	3.0
No. Habitats	3.2	1.4	1.0	6.1
Percent of forested riparian landside	67.4	31.6	0.0	100.0
Percent of forested riparian island	50.1	35.0	0.0	100.0
Distance to levee, miles	2.4	2.2	0.2	8.1

[1]Gravel aerial coverage ranked as follows: no gravel=0, low=1, medium=2, high=3.

Based on the scoring matrix (Table 6), an optimum secondary channel (i.e., score of 1.0) consists of high abundance of gravel usually in the upper reach, greater than four habitats, greater than 50 and 75 % riparian forest cover on the island and landside, respectively, and levees set back greater than 4.0 miles. The mean (±SD) I_h score for the 53 side channels was 0.57 ± 0.12 and was normally distributed (Figure 3).

The total number of dikes in a secondary channel ranged from 0 to 11 (n=53) with a mean of four dikes per secondary channel (Table 7). Dikes were twice as numerous in the upper reach of the secondary channel compared to the middle and lower reaches. The Economy of Restoration Index had a skewed distribution, with most side channels having less than five dikes requiring notching to restore flow (Figure 4). The mean number of dikes was 3.9 corresponding to I_e = 0.6, but due to the negatively skewed distribution (i.e., high frequency of side channels with three to four dikes), the mode was three dikes corresponding to an I_e = 0.7. Only two side channels had the highest score of 1.0, meaning that less than two dikes were present so cost would be low; conservation would be most appropriate for high-scoring channels. About 20% of the side channels had greater than six dikes scoring below 0.5, suggesting that costs would be considerably higher to restore flow in those channels.

Table 6. Metric scoring range for the secondary channel habitat index (I_h), n=53.				
	Metric Score			
Metric	**0.1 Minimum**	**0.33 Low**	**0.66 Moderate**	**1.00 Good**
Relative abundance of gravel	None	Low	Medium	High
Number of habitats	0-1	2-3	4	>4
Percent forested riparian - landside	<25	25-50	51-75	>75
Percent forested riparian - island	0	1-25	26-49	>49
Distance to levee, miles	<0.5	0.5-1.4	1.5-3.9	>3.9

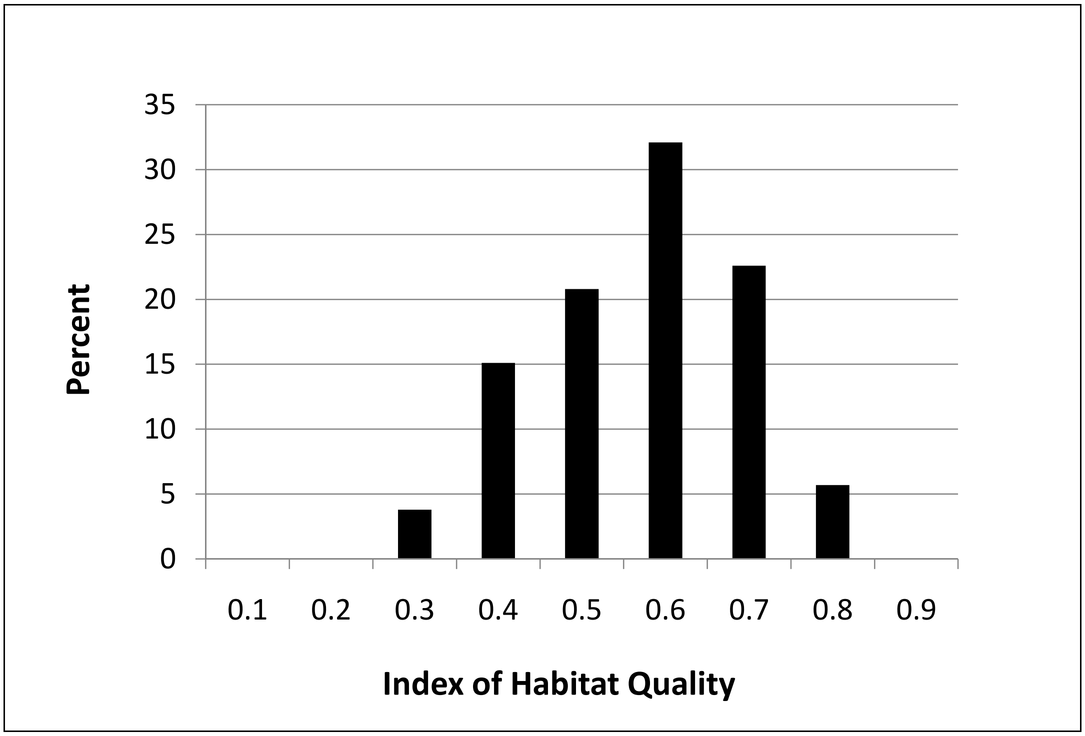

Figure 3. Distribution of Habitat Quality Index (I_h) scores for 53 secondary channels in the lower Mississippi River.

Table 7. Number of dikes per reach for secondary channels in Lower Mississippi River, n=53.		
Variable	**Mean**	**Maximum**
No. Dikes-upper reach	2.2	5.0
No. Dikes-mid-reach	0.8	3.0
No. Dikes-lower reach	0.9	5.0
Ave. No. Dikes - total	3.9	11.0

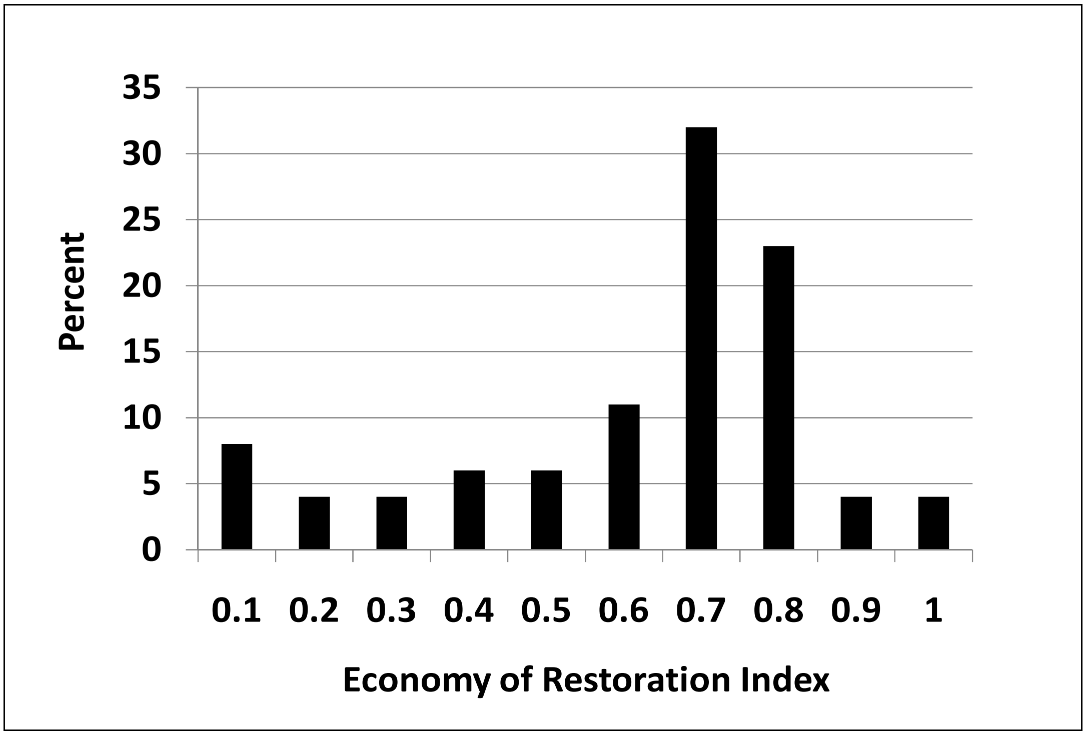

Figure 4. Distribution of the Economy of Restoration Index (I_e) scores for 53 secondary channels in the lower Mississippi River. Higher scores correspond to less cost. Highest cost corresponds to a score of 0.1 for notching greater than eight dikes.

Considering both habitat quality and cost of restoration, the Priority Index (I_p) provides a ranking of side channels that are most cost-effective to restore (Figures 5 and 6). For the 53 side channels evaluated, I_p ranged from 0.1 (low habitat value; high cost due to numerous dikes) to 0.7 (high habitat value; less than two dikes in the channel), with a mean of 0.34 (Figure 7, Appendix B). The 53 side channels analyzed for index development represent a subset of all side channels in the Lower Mississippi River. However, this subset suggests that there are numerous side channels having moderate habitat quality with a relatively high number of dikes, and only a small number of high-ranking channels.

DISCUSSION

Number of secondary channels. Historically, the Mississippi River meandered across the alluvial floodplain forming cut-offs and secondary channels. The secondary channels varied in size and complexity, but were always smaller than the main channel. Prior to river regulation, secondary channels were gained and lost as the river formed new courses to the Gulf of Mexico (Williams and Clouse 2003). However, levees, revetment, and dikes have stabilized the river and floodplain, thus reducing or even eliminating formation of new secondary channels. Consequently, secondary channels have become a finite resource, trending towards reduction in numbers due to sedimentation and loss of connectivity with the main channel.

The total number of secondary channels in the LMR depends on river stage. At high discharge, water moves laterally and reconnects numerous secondary or tertiary channels that otherwise may be completely dry at lower stages. According to Williams and Clouse (2003), 145 secondary

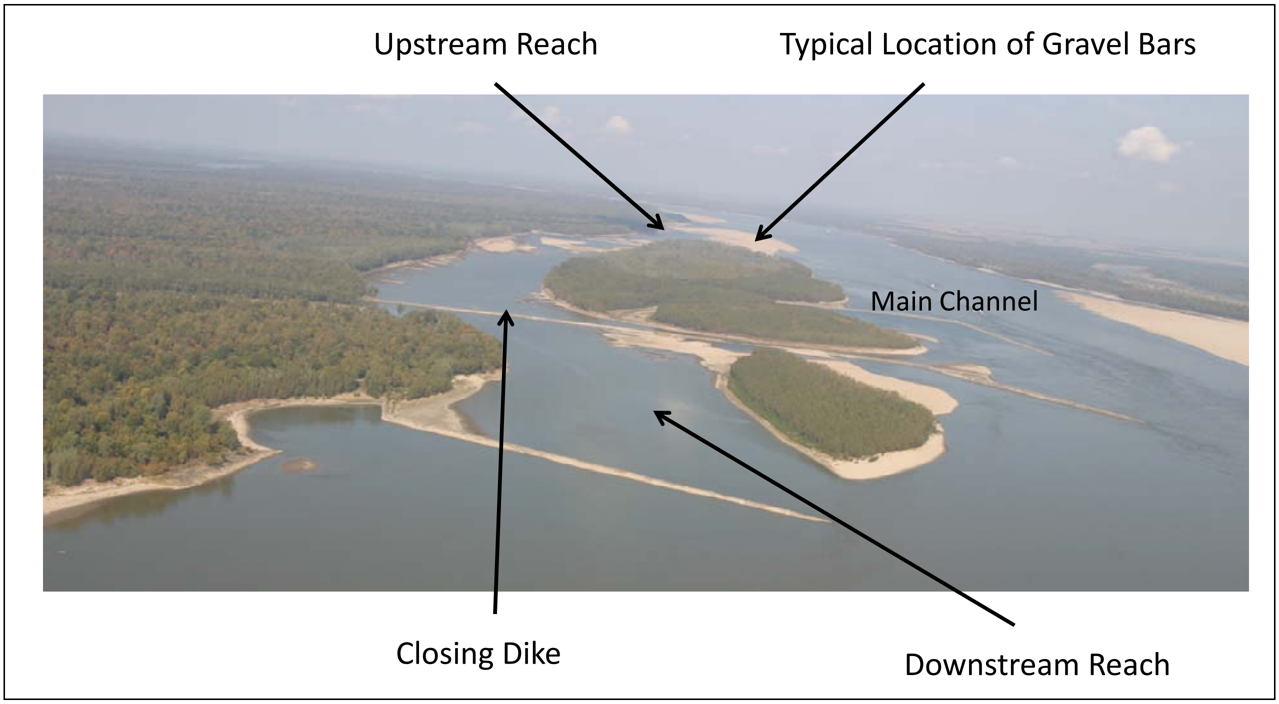

Figure 5. High-quality secondary channel with dikes.

Figure 6. Low-quality secondary channel.

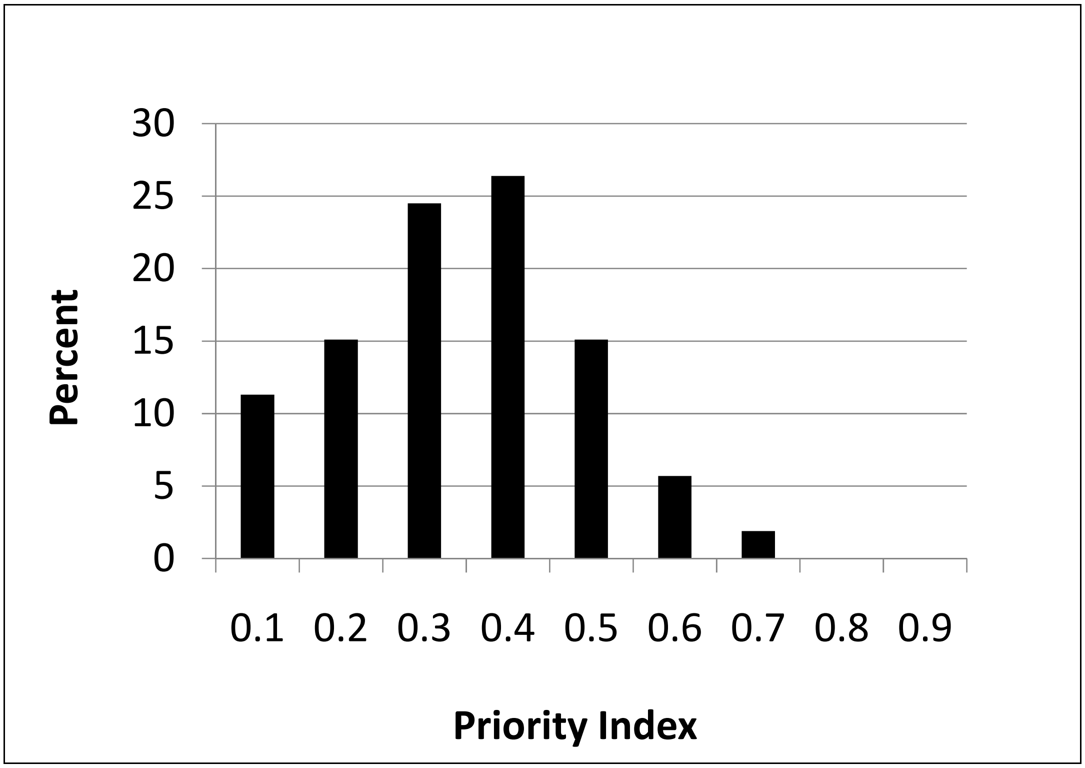

Figure 7. Distribution of Priority Index scores for 53 secondary channels in the lower Mississippi River.

channels existed at one time or another in the LMR over a 40-year period (1960-2000) as identified from hydrographic surveys. However, by the 1990's less than 92 channels existed. For their analysis, a secondary channel was defined as "existing" if there were wetted channel areas and volumes 10 ft above LWRP. The 53 side channels used in the analysis, which was a subset of the total number in the LMR identified by Williams and Clouse (2003), were recognizable from navigation charts because they were associated with well-defined islands visible at a +5 to +10 LWRP. These stages usually occur each year, albeit sometimes for only short time periods.

Limitations. Use of video is limited to low water stages in order to identify habitat complexity. As river stages increase, islands may become flooded and less visible. Therefore, the application of this approach is limited to low water conditions, although distance to levee or natural bluff addresses higher stages to some extent. This does not imply that secondary channels are not important to the overall health of the ecosystem at higher stages. At high stages, the main channel expands onto the floodplain providing access to a variety of habitats. Secondary channels provide velocity refugia from strong currents at high river stages, and may provide greater biotic exports (e.g., detritus, fish, and other aquatic organisms) and lateral connections to other habitat types.

The Index of Habitat Quality does require a degree of subjectivity; human judgment is needed to recognize habitat types and estimate areal contribution of substrate attributes and riparian buffer. However, the metrics used provide a hierarchical assessment in scale from microhabitats (i.e., substrate), macrohabitats (number of different habitats), to landscape variables (i.e., forested riparian and amount of floodplain). Assessments conducted at different scales provide better means of interpreting trends and patterns (Wiens 1989). Because these variables are not redundant and can be easily quantified from remote data sources, the index can be universally used without high in-house cost requirements.

Although the 53 secondary channels used in construction of the index represent a broad cross section in the LMR, not all are represented. An unknown number of relatively shallow, ephemeral secondary channels without well-defined islands that have been severely impacted by geomorphic changes (often accelerated by dike fields) have not been included in this analysis. These ephemeral secondary channels would be of low priority but could still provide habitat benefits from dike notching depending on innovative engineering designs. In addition, the LMR contains a small (<5) number of very long (>10 miles) and sinuous secondary channels that were not included in the video; these should be evaluated for conservation purposes in the future.

<u>Biological relevance</u>. There is minimal connectivity to adjacent floodplain waterbodies when the main channel is mostly confined below banks. During these low-water events, secondary channels may represent the only major waterbody still connected to the main channel. Otherwise, fish and other aquatic fauna are entirely confined to the main channel where deep water and high water velocities may impair survival and growth. Secondary channels offer greater habitat diversity compared to the main channel including expansive slackwater areas, access to backwaters, structurally complex riverbanks, and other attributes that contribute to biotic integrity of aquatic communities.

For most secondary channels in the LMR, the Index of Habitat Quality can characterize prevailing attributes. The index indicates that the majority of channels have only moderate habitat quality, suggesting numerous opportunities for restoration. Most channels have been impacted by closure dikes, resulting in high levels of sedimentation that often cover gravel substrates, shallow water, and early disconnection with the main channel. The index also indicates the presence of a few high-scoring channels that should be targeted for conservation. The number of secondary channels and the direct benefits of dike notching support continued efforts to restore these habitats.

<u>Prioritization</u>. The Priority Index is a composite of habitat quality and restoration cost. Cost was assumed to be directly proportional to the number of dikes requiring notching or removal. LMRCC calculated that the average cost for notching dikes in four LMR side channels using land-based equipment, including mobilization/demobilization, was $25,000. Including in-house project development (developing permit applications, permit application filing fees, maps, engineering design and review costs, etc.) and contract oversight (salary, travel, supplies, etc.) increased the total cost per dike to $30,000. This figure should only be used for planning purposes because each dike notch will have unique requirements relative to the hydrograph, fuel costs, and unexpected site conditions (excessive amounts of sand to remove, large rocks, etc.). However, for those side channels with only a few dikes, return on investment should be high considering the relatively low cost of dike notching and the large area influenced by flow restoration.

The Priority Index was developed to facilitate the planning process for restoring flow in secondary channels by notching dikes. Impacts of dikes are most evident for the low-scoring channels that are shallow and connected only during higher river stages. However, moderate to high scoring channels should be targeted for restoration. Stewardship goals of state and federal agencies include conservation and preservation of rare and unique habitats, such as highly ranked secondary channels. Therefore, all secondary channels should be evaluated and the Priority Index values should be ranked from highest to lowest to ensure that restoration decisions become more objective and quantifiable.

Applications. Once a secondary channel is selected for restoration, the concept of the Habitat Evaluation Procedure (HEP) can be applied (USFWS 1980). Habitat Units (HU) are a derivative of HEP and can be calculated for any secondary channel using the Habitat Quality Index as the weighting factor on acres: HU = I_h * Acres. HU's are a measure of quantity (acres) and quality (index score), and can be used in HEP to plan restoration projects, quantify environmental benefits, and provide a basis for monitoring long-term success (USFWS 1980). The Island 63 secondary channel project in the LMR provides an example of using the Habitat Quality Index to evaluate environmental benefits of restoration.

The LMRCC, in cooperation with the U.S. Army Engineer District, Memphis, constructed a 300-ft notch in a closing dike across the Island 63 secondary channel (see the following for more information: (http://www.lmrcc.org/Island%2063%20LMRCC%20Final_files/frame.htm). The notch increased flow through the channel that scoured sediment in the upper reach, creating additional access to backwaters. Deep pools were formed below the notch and riverine fishes had full access to the channel. In fact, the federally endangered pallid sturgeon (*Scaphiryhnchus albus*) was collected in the secondary channel post-project indicating enhanced connection to the main channel.

As an example application, Habitat Units were calculated for three scenarios: before notching, after notching, and without notching. The without-notching scenario assumed that sedimentation in the upper reach would progress to such an extent that a larger area of the channel would be lost, thus reducing the number of habitats and aquatic area. Therefore, the longer-term perspective of removing sediment before the channel is totally occluded is a viable alternative. The Habitat Quality Index increased with notching due to greater habitat complexity, but decreased without notching due to loss of habitats and overall aquatic area (Table 7). Habitat Units increased 21% with notching, but decreased 70% without notching compared to pre-project conditions. This example illustrates a tractable approach to quantifying benefits of notching closing dikes in secondary channels.

Table 7. An example of habitat gains after notching closing dike in Island 63 secondary channel. Acres and Habitat Quality Index for the "without notching" scenario were assumed.

Time Period	Acres	Habitat Quality Index	Habitat Units	Percent Change
Before	205	0.49	100	-
After	205	0.62	127	+21
Without Notching	100	0.30	30	-70%

Restoration of secondary channels can be relatively inexpensive and influence large aquatic areas of riverine habitat with a high return on investment. In addition, most secondary channels in the lower Mississippi River are within the Corps' authorized boundaries of the Mississippi River and

Tributaries project, making it likely that cooperative efforts with resource agencies will be successful. The index approach described herein can provide the necessary justification and planning tools to move projects forward and provide an approach to monitor ecosystem benefits of restoring or rehabilitating secondary channels. Monitoring or modeling studies will also lead to a better understanding of habitat changes after notching that can be used to refine the index approach. Further studies are ongoing to correlate the Habitat Quality index to fish assemblages in secondary channels and quantify increased periods of river connectivity after closing dikes are notched. These inclusions will provide a more comprehensive assessment of secondary channels and promote continued efforts to make meaningful changes in the condition and function of these primary habitats in the LMR.

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Appendix A. Guidelines for Obtaining Size and Metric Values of Secondary Channels

River stage for viewing

If the river stage of TerraServer photography does not closely match that of the Red Hen video, then choose a higher stage, rather than a lower stage, to avoid the dewatered condition for measurements of length and width of the secondary channel.

Measurements of area

- Reaches – The secondary channel was separated into three reaches of equal length. Width and number of dikes were determined per reach. In an upstream direction, the lower reach began at the lower apex of the island, while the upper reach ended at the upper apex of the island.
- Width – Three measurements are taken: upper, middle, and lower reaches. The upper measurement is taken immediately downstream of the upper apex of the island. The lower measurement is taken immediately upstream of the lower apex of the island. Avoid taking measurements at the apexes, since these areas are usually narrower and do not represent the width of the respective reaches (upper or lower). The middle measurement is taken in the middle of the secondary channel.
- Length – This measurement is taken from the upper apex to the lower apex of the island.

Habitat types. Runs, pools, backwaters, bends, braided islands, braided channel, gravel bars, and tributary mouths. Habitat types must be seen at relatively low water periods when video was acquired. All secondary channels have a primary channel that is not counted as a habitat type. This area may appear to be braided with isolated pools or runs, but should be considered part of the primary channel. Runs, pools, and braided channel habitat types are usually lateral or adjacent to the primary channel.

- Runs – Runs are narrow, fast-flowing channels often associated with sediment plugs.
- Pools – Pools are separated from the channel, usually isolated or with one or two small, connecting channels.
- Backwaters – Backwaters must extend at least two channel widths into the trees or floodplain with open water visible (not just flooded hardwoods) and an obvious low-water connection. Scallops below dikes are not backwaters.
- Channel bends – A channel bend is one complete “S,” or in other words, two complete bendways. Most secondary channels have just one bendway.
- Braided islands – The main island does not count as habitat unless braided.
- Braided channel – This should be a clearly visible channel not due to low water.
- Gravel bars – Gravel observed on the video, usually at the upstream end of islands. Any amount of gravel visible on the video is considered to be a gravel bar habitat. To estimate

the relative abundance of gravel and determine the gravel metric value, the following categories were identified.

- Low – no patches of gravel
- Medium – obvious patches, but scattered
- High – continuous, homogenous gravel

- Tributary mouth – The downstream confluence of a tributary or an outlet channel of a floodplain lake with a direct connection to the secondary channel.

Riparian zone. Aerial photography usually provides a better landscape view of riparian features. Video may be restricted to near-channel features and omit the entire riparian zone. The forested riparian zone is estimated landside and island side:

- Landside - The area of the riparian forested zone to be considered is two times the maximum width of the secondary channel (usually middle reach), or up to the levee, whichever comes first.
- Islandside - The area of the riparian forested zone to be considered includes the entire island.

Distance to levee. Measured as the distance between the levee (on the same bank side as the secondary channel) and the point of the secondary channel nearest the levee.

Appendix B: Summary of size, metric values, and index values

(RDB = Right Descending Bank; LDB = Left Descending Bank)

SITE	State	River Mile	Bank	Length, Miles	Width, Feet	Acres	Dikes	Gravel	Habitats	Forested Island, Percent	Forested Landside, Percent	Distance to Levee, Miles	Habitat Quality Index	Economy of Restoration Index	Priority Index
Fritz Island Dikes	LA	337	RDB	2.9	449.31	161	3	low	3	0	50	0.8	0.3533	0.7	0.2473
Warincott	MS	347	LDB	3.7	1004.16	457	4	none	4	75	25	0.9	0.44	0.6	0.264
Carthage	MS	357	LDB	1.2	941.13	143	2	none	2	75	50	4.1	0.62	0.8	0.496
Spithead Towhead Dikes	LA	383	LDB	2.8	763.52	270	4	none	3	0	100	6.6	0.5067	0.6	0.304
Opposite Cottage Bend	LA	390	LDB	1.3	704.1	63	5	none	3	100	100	0.3	0.5067	0.5	0.2533
Bondurant Towhead Dikes	LA	395	RDB	3.2	2067.24	710	3	none	2	50	50	1.4	0.4867	0.7	0.3407
Arcadia Point	MS	468	LDB	3.5	1287.51	143	3	medium	2	50	100	3	0.7333	0.7	0.5133
Ajax	MS	481	LDB	4.8	1683.23	467	6	low	3	50	100	1.3	0.6	0.4	0.24
Wilson Point Dikes	LA	499	RDB	3.5	533.43	235	3	none	4	75	50	5.9	0.6867	0.7	0.4807
Corregidor	MS	503	LDB	2.7	582.19	197	2	low	3	100	0	1.1	0.42	0.8	0.336
Lower Cracraft	AR	510	RDB	4.3	1372.34	688	3	low	4	50	50	1	0.6	0.7	0.42
Carolina Chute	AR	515	LDB	3.9	376.11	40	2	low	1	25	75	0.5	0.3533	0.8	0.2827
Kentucky Bend	AR	519	LDB	4.3	1293.99	585	1	none	4	100	75	1.6	0.62	0.9	0.558
Anconia	MS	528	RDB	1.1	390.44	39	3	low	2	100	100	1	0.6	0.7	0.42
Lake Port Towhead	AR	529	LDB	6.7	1033.97	866	3	none	2	0	25	1.7	0.26	0.7	0.182
Chicot Landing	AR	558	RDB	3.9	1465.51	709	4	low	3	50	100	0.6	0.6	0.6	0.36
Catfish Point	MS	570	LDB	2.2	1101.19	104	2	medium	2	0	100	1.6	0.5533	0.8	0.4427
Below Prentiss	MS	578	LDB	2.4	809.31	237	4	low	1	0	100	6.6	0.5067	0.6	0.304
Terrene	MS	580	LDB	1.7	561.8	29	4	medium	2	100	0	0.8	0.4867	0.6	0.292
Victoria Bend	AR	595	RDB	1.3	624.13	98	4	low	3	25	100	7.9	0.6	0.6	0.36
Old White River	MS	597	RDB	8.4	633.98	666	0	none	3	100	50	6.2	0.62	1	0.62
Island 70	MS	604	LDB	2.6	849.08	223	11	high	3	50	50	0.8	0.6667	0.1	0.0667
Island 69	AR	615	RDB	4.9	834.17	513	6	medium	6	25	75	1.4	0.6	0.4	0.24
Lulow Chute Island 68	AR	620	RDB	2.2	543.52	146	2	medium	2	50	100	0.5	0.6667	0.8	0.5333
Island 67	MS	620	LDB	2.2	1555.19	417	2	none	1	0	100	4.1	0.46	0.8	0.368
Sunflower Cutoff	MS	626	RDB	2	705.42	177	3	none	3	100	100	1.1	0.5533	0.7	0.3873
Island 64	AR	630	RDB	2.8	1343.57	333	3	low	4	50	100	0.7	0.6667	0.7	0.4667
Island 62	AR	636	RDB	2.2	744.73	206	3	low	3	50	50	1.6	0.6	0.7	0.42
Island 63	MS	637	LDB	5.1	325.68	205	2	none	3	100	75	0.5	0.4867	0.8	0.3893
Kangaroo Point	AR	650	RDB	3.1	532.62	65	3	none	2	50	100	0.4	0.5067	0.7	0.3547
Montezuma Towhead	MS	655	RDB	1.8	1062.22	181	3	medium	4	75	25	0.9	0.5533	0.7	0.3873
Prairie Point	AR	664	RDB	2.3	1413.36	397	3	medium	5	100	25	1.8	0.6867	0.7	0.4807
St Francis Bend	MS	670	LDB	1.2	1052.11	152	2	none	1	25	100	5.2	0.5067	0.8	0.4053
Walnut Bend	AR	676	RDB	1.8	1095.79	248	3	low	2	50	100	2.1	0.6667	0.7	0.4667
Bordeaux Point	MS	681	LDB	1.5	409.32	79	2	medium	2	50	50	4.8	0.7333	0.8	0.5867
Rabbit Island	MS	692	LDB	3	1166.94	442	3	none	2	0	100	2.9	0.44	0.7	0.308
Cat Island	AR	711	RDB	3	1262.57	465	10	medium	4	75	50	0.7	0.6667	0.1	0.0667
Ensley/Armstrong	TN	726	RDB	2.9	1272.82	460	11	medium	6	75	75	0.5	0.7333	0.1	0.0733
Redman Lossahatchie	TN	743	RDB	5.1	1261.22	795	7	high	6	100	100	0.2	0.82	0.3	0.246
Hickman Randolph	TN	749	LDB	4.4	777.55	422	6	low	5	25	100	1.3	0.6	0.4	0.24
Richardson Landing	TN	768	LDB	0.8	494.08	52	2	low	2	0	50	0.6	0.3533	0.8	0.2827
Lookout	AR	770	RDB	0.9	733.63	80	8	low	2	25	0	2.2	0.3533	0.2	0.0707
Plum Pt	TN	788	LDB	1.4	693.7	120	3	low	4	25	50	6.4	0.6	0.7	0.42
Keyes Pt	TN	792	LDB	6	771.36	578	8	low	3	50	25	8.1	0.5533	0.2	0.1107
Ashport	AR	793	RDB	2	761.85	188	9	medium	4	50	25	0.7	0.5533	0.1	0.0553
Island 25	AR	805	RDB	1.6	897.7	117	2	medium	4	0	100	6.8	0.6867	0.8	0.5493
Wright Pt Tamm Bend	TN	820	RDB	3.7	1015.4	468	7	low	5	100	50	2.3	0.7333	0.3	0.22
Island 21	TN	829	LDB	4	769.27	385	1	low	4	25	75	1.4	0.4667	0.9	0.42
Island 18 Dikes	TN	832	LDB	3.1	1133.5	435	3	low	1	0	75	3.9	0.3733	0.7	0.2613
Hathaway Dikefield	TN	850	LDB	3.8	422.62	202	5	none	4	75	100	4.3	0.7533	0.5	0.3767
Near Donaldson Point	KY	907	RDB	1	447.76	55	3	none	2	25	50	4.8	0.4867	0.7	0.3407
3 States Towhead	KY	915	RDB	7.5	1207.11	1134	5	medium	6	75	50	0.2	0.6867	0.5	0.3433
Wolf Island	KY	935	LDB	4.1	2121.79	282	1	high	6	75	50	0.3	0.7533	0.9	0.678